SOLAR DOMESTIC HOT WATER FOR AN 84 APARTMENT UNIT

Prepared for

MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

SOLAR DOMESTIC HOT WATER FOR AN 84 APARTMENT UNIT

Prepared by

Major T. Caldwell
Horizon Lodge Inc.
701 South Wisconsin
Conrad, MT 59425

August, 1979

Prepared for

Montana Department of Natural Resources and Conservation
32 South Ewing, Helena, Montana 59620
Renewable Energy and Conservation Program
Grant Agreement Number 145-771

I OBJECTIVES

The intent of the project was to demonstrate the application of solar energy for existing large multi-family dwelling units. The project is feasible in original construction or as a retrofit. In evaluating the optimum yield for dollar cost it was decided that the use of solar energy as an alternate source for heating domestic water was most feasible because of the year round use as opposed to a hot water space heating system application. The space allocated for collector use was adequate for heating domestic hot water, but not enough space was available to supply a significant percentage to the hot water space heating system in the building. In addition, the existing space heating system was designed for higher temperature hot water so use of solar would have required either major system changes at considerable expense or solar use would be limited to partial load conditions.

II PROJECT IMPLEMENTATION

1. Project Planning and Equipment Acquisition

After developing objectives and acquiring raw data for water consumption, gas consumption, and theoretical solar heating production it was determined the project needed professional help for the proposal and a source to interpret the raw data. Drapes Engineering was contracted for the solar system design on July 18, 1978.

The owners did research into two main areas of concern; location of the mechanical components for the proposed system and the choice of collectors. Contact was made with a representative of a new firm just developing convex tracking collectors with the idea of utilizing the limited collector location space to allow for as much energy collection as possible. After comparing efficiency factors of convex collectors against flatplate collectors it was determined that the small percentage advantage was not great enough as opposed to the following negative factors: maintenance cost, difficulty of electronic control maintenance, questionable warranty and company representative availability.

The final choice for the solar collectors was made based on proven reliability, simplicity of maintenance and a state-based supplier. The owners selected Sunworks 3' x 7' flatplate collectors and decided on a direct purchase by owners thereby assuming responsibility for warranties and guarantee of operation of collector jointly with the supplier. This purchase allowed for a 15% savings in collector costs. All other equipment was supplied by the contractor.

II PROJECT IMPLEMENTATION (CONT'D)

1. Project Planning and Equipment Acquisition (Cont'd)

A major consideration at this time was the physical size and capacity of storage tanks. The storage tank size was dictated by the least expensive method of bringing them into the building location. The final decision was to break the necessary design volume into two units that could be brought in the building with minimum alteration of existing walls and entrances.

2. System Installation

The job was initially bid on March 15, 1978, but the lowest bid was over the funded amount for the project. The project was renegotiated with the DNRC and scope of the project was subsequently reduced as follows:

a. Handling and markup costs for the solar collectors were eliminated by the owners making a direct purchase.

b. The responsibility for nonmechanical items such as brick wall removal to provide access for storage tanks and new wall construction was accepted by the owner to reduce overall cost factors and expedite negotiations on the contract.

c. New wiremold and convenience outlets were omitted.

d. Gauge well thermostats for remote temperature sensor locations were used instead of a control temperature control readout panel with remote temperature sensors.

2. System Installation (Cont'd)

e. Interior pipe insulation was omitted with the exception of the heat exchanger and storage tanks. Armaflex insulation was installed on all exterior piping instead of foamed-in-place insulation with a sheet metal enclosure and Armaflex on pipe outside the sheet metal box as was originally specified.

Nelson Plumbing and Heating was contracted to complete the revised job on May 25, 1978. The system was installed and punch list items completed on May 7, 1979.

3. System Modification

Several modifications were made to the system design while the project was under construction.

A pressure relief valve was installed in the water circuit on the outlet of the heat exchanger to provide overpressure protection for the storage tanks. This protection is especially required when the storage tanks are valved off from the city system.

A Powers #11 mixing valve was called for on the original drawings to reduce supply temperature from the solar storage tanks if it exceeded the normal system supply temperature. This mixing valve requires continuous flow for proper operation so was changed to a Powers #434 which does not have the continuous flow requirement.

The expansion tank connection of the antifreeze circuit was changed from the location shown on the drawings to the collector side of

3. System Modification (Cont'd)

the motorized valves on the return line from the collectors. This change was required because the original design did not allow for antifreeze expansion when the motorized valves were closed. Changing the location of the expansion tank solved the problem.

The Rho Sigma #500 temperature controller originally specified is a proportional control designed to work with a variable speed pump. A single speed pump which is less expensive was used in the design so a Rho Sigma #106 differential controller that would be compatible with the pump was substituted.

4. System Performance

The first step in determining system performance was to estimate the efficiency of the backup hot water boiler. A gas meter and a water meter were provided by the owner for monitoring purposes. The solar system was bypassed from July 12, to July 24. Readings were taken during this period from the water meter and the gas meter in addition to system inlet temperature and outlet temperature. Water temperatures were fairly consistent throughout with an average inlet temperature of 55^{O}F and an outlet temperature of 145^{O}F. Hot water consumption for the period was 20,520 gallons and natural gas consumption was 25 MCF. Efficiency of the backup boiler are calculated as follows:

Energy In = 25 MCF X 900,000 Btu/MCF = 22,500 MBtu.

Energy Out = 20,520 Gallons X 8.35 Lbs./Gallons X 90^{O} X Btu/Lb^{O} = 15,421 MBtu

Efficiency = 15,421/22,500 = 69%.

4. System Performance (Cont'd)

No solar system performance information has become recorded to date. This information may become available from the owner after the system has been operating for a period of time. (See Section IV Monitoring.)

5. System Cost

The following cost breakdown was supplied by the mechanical contractor.

	Material	Labor
a. Collector Installation	$ 344.00	$ 3,291.00
b. Collector support structure fabrication	5,415.00	4,123.00
c. Collector support structure installation	3,018.00	612.00
d. Collector piping	3,776.00	6,748.00
e. Intermediate piping	2,510.00	2,531.00
f. Mechanical Room Piping	5,045.00	4,218.00
g. Mechanical Room Equipment	11,114.00	2,731.00
h. Controls	4,166.00	844.00
	$35,388.00	$25,098.00

Horizon Lodge had expenses of $12,428.00 for solar collectors and $1,200.00 outside of the contract for internal staff labor and materials to redo the wall and doors into the mechanical room, painting and outside entry replacement. The $1,200.00 represents $605.00 in labor and $595.00 in materials.

Total Cost = $35,388.00 + $25,098.00 + $12,428.00 + $1,200.00 = $74,114.00.

6. Economic Evaluation

The f-chart analysis for this system showed that the 906 SF domestic hot water system would provide an estimated 52% of the 504 MMBtu/Yr. heat load. Assuming that the conventional hot water heater efficiency is 65% on an annual basis and that the average cost of natural gas is $2.55/MMBtu the annual cost of water heating is:

504 X 2.55/.65 = $1,977.00/year

The cost savings can be estimated at:

$1,977.00 X .52 = $1,028.00/year

The simple payback is 74,114/1026 = 72 years

III CONCLUSIONS AND RECOMMENDATIONS

There have been no problems to date with the operation of the system. Typical solar storage temperatures of 125°F in the evening and 80°F in the morning have been obtained. A major goal of the project was realized; obtaining detailed cost data for a large retrofit DHW system. The necessary metering equipment has been installed to obtain performance data.

A suggested modification to the existing system would be to set the water outlet temperature at 115°F instead of the present 145°F.

High solar storage temperatures have not been a problem. Storage temperatures have not exceeded 150°F even when the solar system was bypassed for several days to determine efficiency of the hot water boiler. It is probable that the dry cooler would not be required on systems of this type. Additional savings could be obtained by elimination of the mixing valve (to maintain a set maximum temperature) but only after careful study of system load, solar storage, etc. show that the high temperatures will not be a problem. Performance data from this project will be useful in determining the need of these items on similar future installations.

IV MONITORING

The desired information from a monitoring program on this project would be the percent of load by solar heating on a monthly basis. To get this information, it is necessary to measure the following:

1. total flow of water through the system
2. the monthly average inlet water temperature
3. the monthly average outlet water temperature
4. the total amount of backup heating fuel
5. the efficiency of the backup heating system

The owner has provided a gas meter and a water meter for monitoring.

The efficiency of the backup hot water boiler should be determined on a seasonal basis by bypassing the solar system for several days and measuring the system inlet temperature, outlet temperature, water use, and gas consumption.

During normal operation, the monitoring would require that the owner make several water temperature readings during the month and then take gas and water meter readings at the end of each month. An estimate of the monthly percent of load can be determined from this information assuming a constant backup heater efficiency.

Total Load = (Outlet Temp. - Inlet Temp.) X Water Use (Gallons) X 8.35

Backup Energy = Gas Use (MCF) X 900,000 X Efficiency of Backup System

Solar Fraction = (Total Load - Backup Energy)/Total Load

V PUBLIC AVAILABILITY

1. Horizon Lodge domestic hot water solar system will be available for individuals and groups to review by appointment 9 to 5 p.m. week days.

2. The estimated number of general public viewing the project during the last month of construction and first month of operation were approximately 55 persons which included three groups with an average number of twelve. The present residents of Horizon Lodge (93) have all viewed the project and continue to monitor activities daily. The longest distance traveled by individual or group was 150 miles one-way.

VI PROGRAM EVALUATION

My personal evaluation of the renewable energy program is:

1. The state offices maintain a very high level of monitoring progress of projects and good financial auditing of project fund requests. The delay in state offices providing funds when payment requests are made does create some difficulty with larger contracted projects.

2. I would recommend some form for recording monitoring of the various energy factors in larger projects such as Horizon Lodges'. This would provide greater accuracy in the data gathering processes therefore providing more accurate, efficient results.

3. The domestic solar project appears to be providing a higher level of efficiency when originally projected. I feel the eventual data accumulated will be very helpful to future commercial applications.

4. The residents of Horizon Lodge were at first unconvinced of the value of this project. Since the project has been completed and they have been exposed to the actual temperatures produced by the system and have begun to understand the dollar factor in savings. They have become very enthused, supportive and proud that they have the project in their building.

Major Caldwell
Administrator - Horizon Lodge

Horizon Lodge, Conrad, Mt.

DOMESTIC WATER TANK September 1981

DAY	TIME	GALLONS
9	06:30 AM	
	07:30 AM	150
	08:30 AM	70
	09:30 AM	140
	10:30 AM	60
	11:30 AM	80
	12:30 PM	30
	1:30 PM	100
	2:30 PM	110
	3:30 PM	30
	4:30 PM	60
	5:30 PM	40
	6:30 PM	60
	7:30 PM	40
	8:30 PM	30
	9:30 PM	40

DAY	TIME	GALLONS
11	06:30 AM	140
	07:30 AM	130
	08:30 AM	140
	09:30 AM	100
	10:30 AM	50
	11:30 AM	60
	12:30 PM	60
	1:30 PM	50
	2:30 PM	70
	3:30 PM	40
	4:30 PM	40
	5:30 PM	40
	6:30 PM	140
	7:30 PM	30
	8:30 PM	50
	9:30 PM	30

DAY	TIME	GALLONS
13	06:30 AM	180
	07:30 AM	150
	08:30 AM	140
	09:30 AM	150
	10:30 AM	130
	11:30 AM	70
	12:30 PM	50
	1:30 PM	50
	2:30 PM	110
	3:30 PM	50
	4:30 PM	30
	5:30 PM	40
	6:30 PM	90
	7:30 PM	10
	8:30 PM	40
	9:30 PM	50

DAY	TIME	GALLONS
10	06:30 AM	200
	07:30 AM	160
	08:30 AM	110
	09:30 AM	180
	10:30 AM	70
	11:30 AM	110
	12:30 PM	60
	1:30 PM	50
	2:30 PM	130
	3:30 PM	60
	4:30 PM	120
	5:30 PM	40
	6:30 PM	110
	7:30 PM	50
	8:30 PM	90
	9:30 PM	30

DAY	TIME	GALLONS
12	06:30 AM	250
	07:30 AM	140
	08:30 AM	110
	09:30 AM	170
	10:30 AM	50
	11:30 AM	40
	12:30 PM	50
	1:30 PM	90
	2:30 PM	110
	3:30 PM	70
	4:30 PM	90
	5:30 PM	40
	6:30 PM	90
	7:30 PM	30
	8:30 PM	30
	9:30 PM	90

DAY	TIME	GALLONS
	06:30 AM	
	07:30 AM	
	08:30 AM	
	09:30 AM	
	10:30 AM	
	11:30 AM	
	12:30 PM	
	1:30 PM	
	2:30 PM	
	3:30 PM	
	4:30 PM	
	5:30 PM	
	6:30 PM	
	7:30 PM	
	8:30 PM	
	9:30 PM	

Horizon Lodge, Conrad, Mt.

DOMESTIC WATER TANK September 1981

DAY	TIME	GALLONS	DAY	TIME	GALLONS	DAY	TIME	GALLONS
9	06:30 AM	2358320	11	06:30 AM	2361070	13	06:30 AM	2363730
	07:30 AM	2358470		07:30 AM	2361200		07:30 AM	2363880
	08:30 AM	2358540		08:30 AM	2361340		08:30 AM	2364020
	09:30 AM	2358680		09:30 AM	2361440		09:30 AM	2364170
	10:30 AM	2358740		10:30 AM	2361490		10:30 AM	2364300
	11:30 AM	2358820		11:30 AM	2361550		11:30 AM	2364370
	12:30 PM	2358850		12:30 PM	2361610		12:30 PM	2364420
	1:30 PM	2358950		1:30 PM	2361660		1:30 PM	2364470
	2:30 PM	2359060		2:30 PM	2361730		2:30 PM	2364580
	3:30 PM	2359090		3:30 PM	2361770		3:30 PM	2364630
	4:30 PM	2359150		4:30 PM	2361810		4:30 PM	2364660
	5:30 PM	2359190		5:30 PM	2361850		5:30 PM	2364700
	6:30 PM	2359250		6:30 PM	2361990		6:30 PM	2364790
	7:30 PM	2359290		7:30 PM	2362020		7:30 PM	2364800
	8:30 PM	2359320		8:30 PM	2362070		8:30 PM	2364840
	9:30 PM	2359360		9:30 PM	2362100		9:30 PM	2364890

DAY	TIME	GALLONS	DAY	TIME	GALLONS	DAY	TIME	GALLONS
10	06:30 AM	2359560	12	06:30 AM	2362350		06:30 AM	
	07:30 AM	2359720		07:30 AM	2362490		07:30 AM	
	08:30 AM	2359830		08:30 AM	2362600		08:30 AM	
	09:30 AM	2360010		09:30 AM	2362770		09:30 AM	
	10:30 AM	2360080		10:30 AM	2362820		10:30 AM	
	11:30 AM	2360190		11:30 AM	2362860		11:30 AM	
	12:30 PM	2360250		12:30 PM	2362910		12:30 PM	
	1:30 PM	2360300		1:30 PM	2363000		1:30 PM	
	2:30 PM	2360430		2:30 PM	2363110		2:30 PM	
	3:30 PM	2360490		3:30 PM	2363180		3:30 PM	
	4:30 PM	2360610		4:30 PM	2363270		4:30 PM	
	5:30 PM	2360650		5:30 PM	2363310		5:30 PM	
	6:30 PM	2360760		6:30 PM	2363400		6:30 PM	
	7:30 PM	2360810		7:30 PM	2363430		7:30 PM	
	8:30 PM	2360900		8:30 PM	2363460		8:30 PM	
	9:30 PM	2360930		9:30 PM	2363550		9:30 PM	

MECHANICAL LEGEND

- DOMESTIC COLD WATER
- DOMESTIC HOT WATER
- DOMESTIC RECIRCULATING HOT WATER
- S — SANITARY SEWER SOIL AND WASTE
- V — V — SANITARY SEWER VENT
- D — SPECIAL EQUIPMENT DRAIN
- GLYCOL SUPPLY
- GLYCOL RETURN
- PIPE UP
- PIPE DOWN
- ECCENTRIC REDUCER
- UNION
- STRAINER
- BALANCE STATION FLOW INDICATOR
- A.V. AIR VENT
- VALVE IN VERTICAL PIPE
- TEMPERATURE GAUGE OR THERMOMETER
- P PRESSURE GAUGE
- GATE VALVE
- GLOBE VALVE
- CHECK VALVE
- BALANCE COCK
- 3-WAY VALVE
- MOTORIZED VALVE
- R RELIEF VALVE
- FLOW SWITCH

ABBREVIATIONS

E.A.	EXHAUST AIR
VIB. ISOL.	VIBRATION ISOLATOR
I.G.W.	INSTRUMENT GAUGE WELL

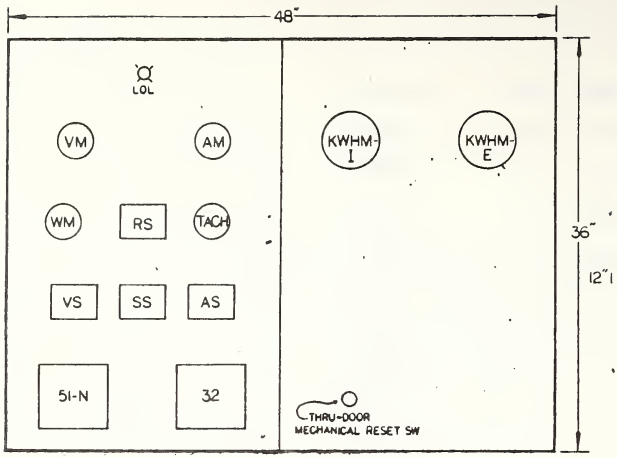
SYMBOLS

- NOTE DESIGNATION
- PLUMBING FIXTURE MARK
- HEATING OR COOLING UNIT IDENTIFICATION
- INDICATES POINT OF NEW CONNECTION TO EXISTING SYSTEM

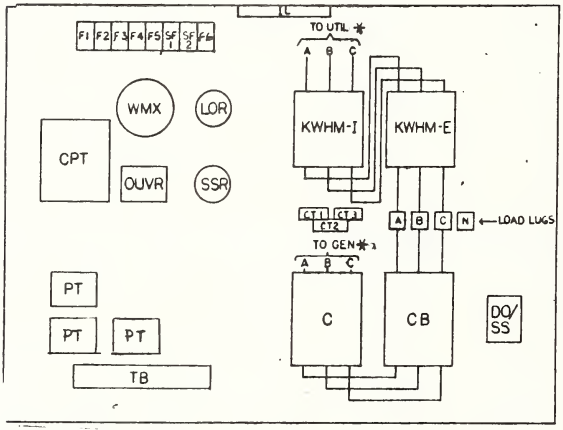
T THERMOMETER OR REMOTE READOUT

ELECTRICAL LEGEND

- PANEL
- STARTER - COMBINATION MAGNETIC
- STARTER - MAGNETIC
- FRACTIONAL HP. MOTOR SENTINEL
- DISCONNECT SWITCH
- BRANCH CIRCUIT CONCEALED IN WALL OR CEILING
- BRANCH CIRCUIT CONCEALED IN OR UNDER FLOOR
- BRANCH CIRCUIT - RUN EXPOSED
- HOME RUN TO PANEL. NUMBER OF ARROWS INDICATES NUMBER OF CIRCUITS.
- NUMBER OF HASHMARKS INDICATES NUMBER OF CONDUCTORS. NO HASHMARKS INDICATES TWO CONDUCTORS.
- M MOTOR
- SPECIAL EQUIPMENT OUTLET
- J JUNCTION BOX OR J-BOX
- INCANDESCENT LIGHT FIXTURE (CEILING OR WALL MOUNT)
- FLUORESCENT LIGHT FIXTURE
- DUPLEX CONVENIENCE RECEPTACLE
- S SWITCH



FRONT LAYOUT



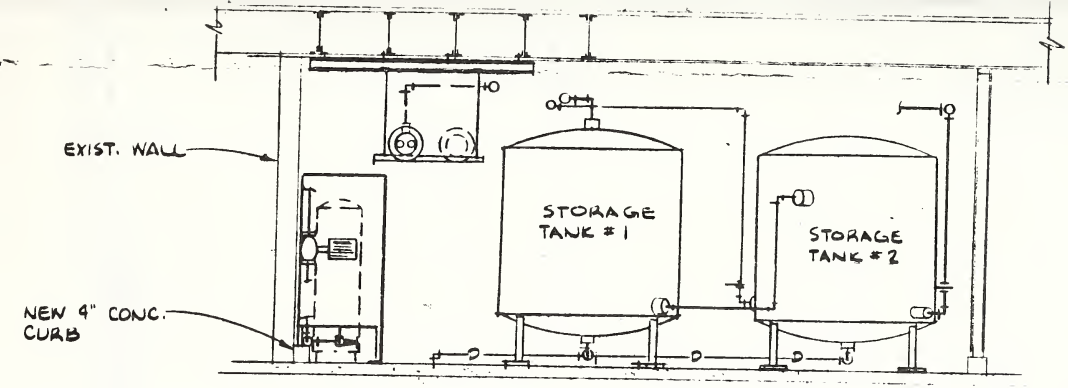
LEGEND

1. AR - A.C. AMMETER
2. AS - AMMETER SWITCH
3. CPT - CONTROL POWER XFMR.
4. DS/RS - DUPLEX OUTLET/SWITCH, GR.
5. IL - ILLUMINATION LIGHT
6. KWHR - KILOWATT-HOUR METER
7. LOL - LOCKOUT LIGHT
8. LOR - LOCKOUT RELAY
9. OVAR - OVER/UNDER VOLT. RLY.
10. PT - POTENTIAL TRANSFORMER
11. RS - RESET SWITCH
12. SS - SYNCHRONIZATION SWITCH
13. SSR - SPEED SENSING RELAY
14. TACH - TACHOMETER
15. TB - TERMINAL BLOCK
16. VM - A.C. VOLTMETER
17. VS - VOLTMETER SWITCH
18. WM - WATTMETER
19. WTX - WATTMETER TRANSDUCER
20. XT - REVERSE POWER RELAY
21. 51-N - A CURRENT RELAY

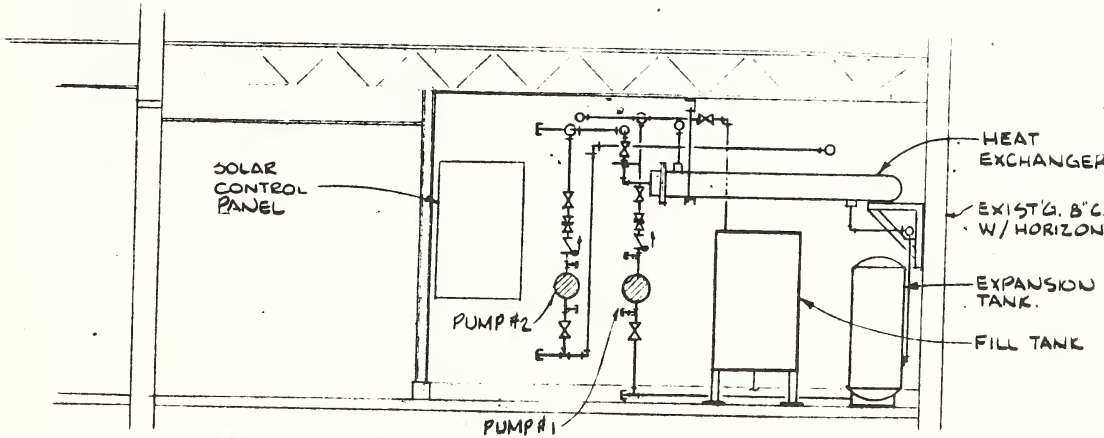
REVISIONS			
LTR	DATE	DESCRIPTION	BY
A	5-1-81	AS BUILT	DB
B	7-6-81	FIELD MODIFICATIONS AS BUILT ADDED PTS	DB

9 8

CUSTOMER	ENERGY EQUIP. CO.	P.O.	
DESCRIPTION	LAYOUT	DRN. APPROVED DB	SCALE N.A.
DRG. RELEASE	6-7-81	ENGINEER APPROVAL DATE	DRAWN BY MBV
4-29-81		PRODUCTION DATE	DATE 4-24-81
5-4-81 SBL		P.C.B.I. NO.	REVISION A
CERTIFIED ELECTRO MFG. CO., INC. 14 S. IDAHO SEATTLE, WA. 98134		DRAWING NO. CD-4052	SHT NO. 1 - 3



1 SECTION 1/4"=1'—0"



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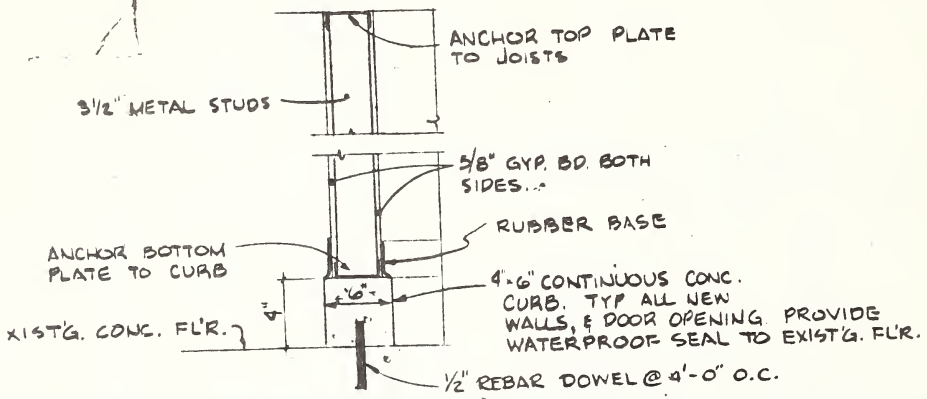
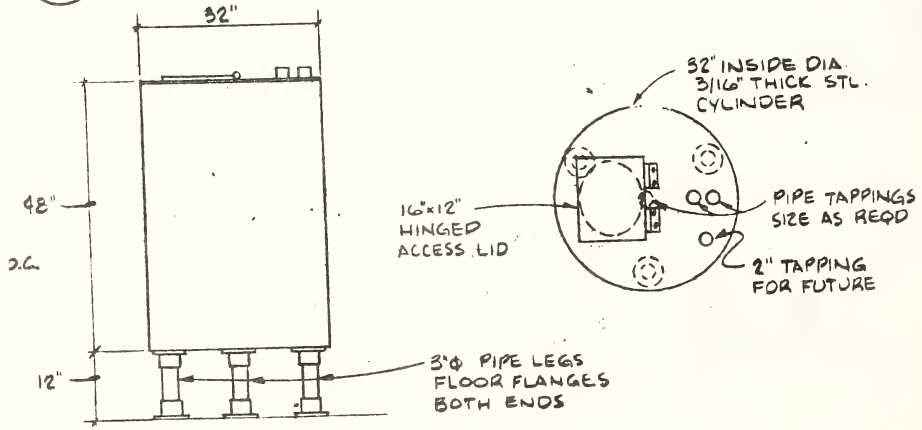
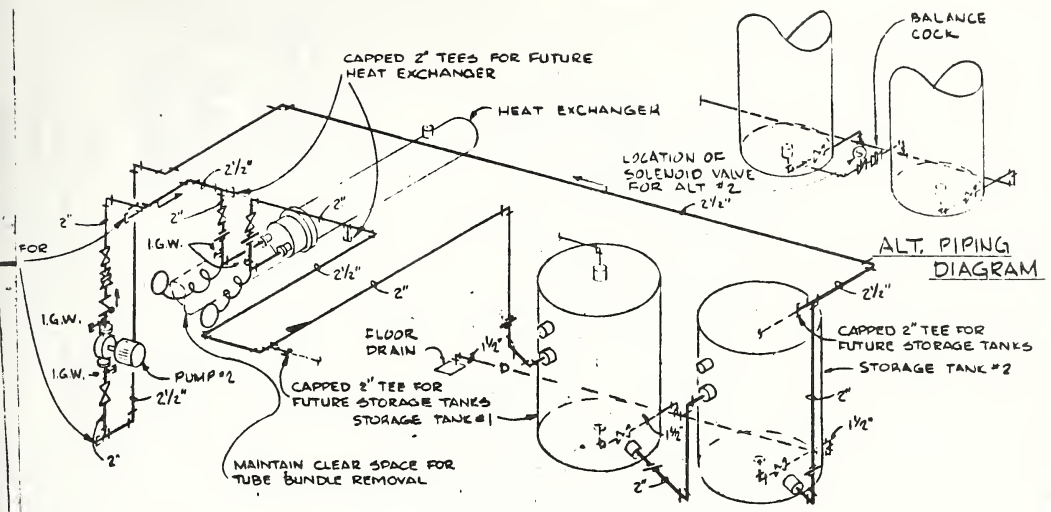


3 SECTION 1" = 1'-0"

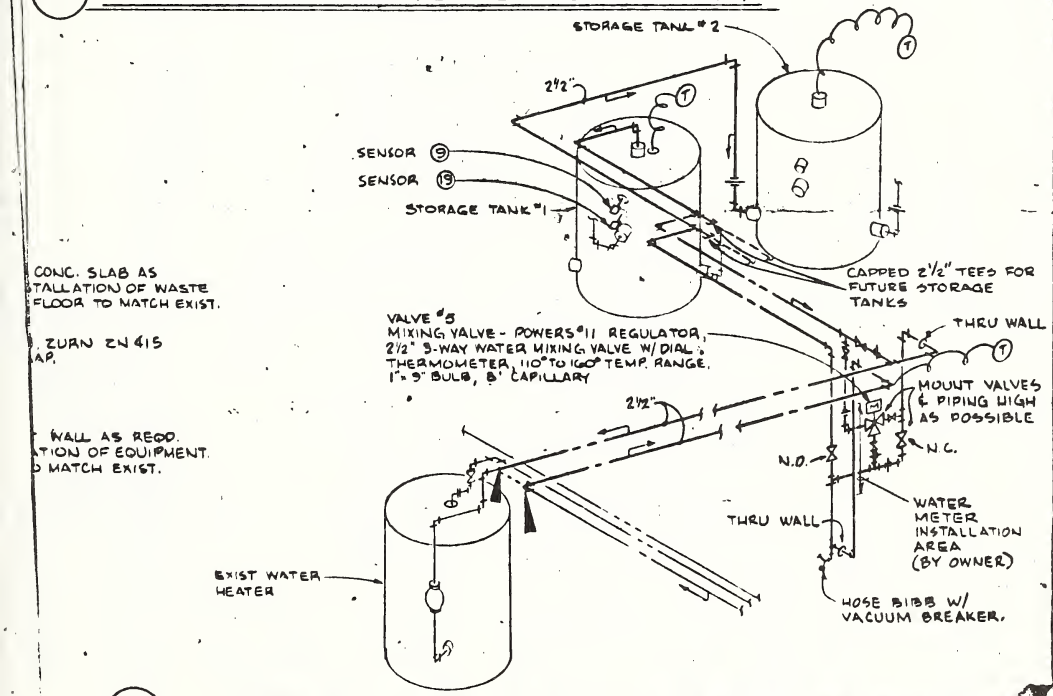


4 FILL TANK DETAIL 1/2" = 1'-0"



ALT. PIPING DIAGRAM

5 HEAT EXCHANGER CIRCUIT PIPING

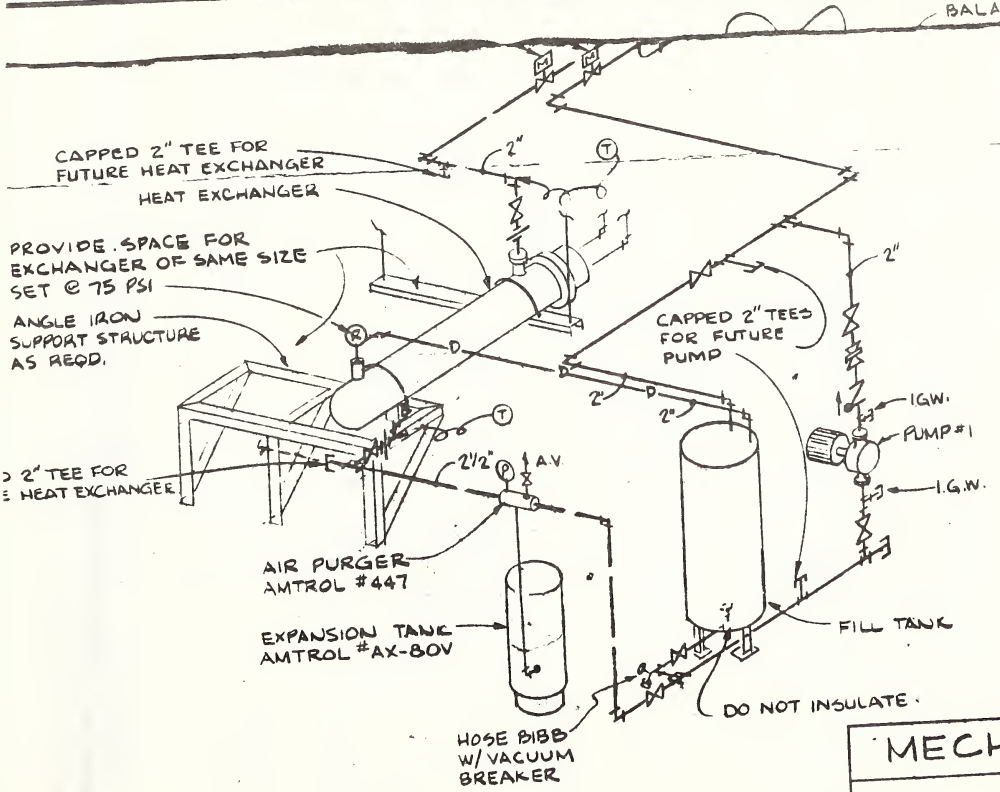


CONC. SLAB AS
STALLATION OF WASTE
FLOOR TO MATCH EXIST.

ZURN ZN 615
AP.

WALL AS REQD.
TION OF EQUIPMENT.
MATCH EXIST.

6 DOMESTIC WATER CONNECTION PIPING DIAG



7 GLYCOL CIRCUIT PIPING DIAGRAM

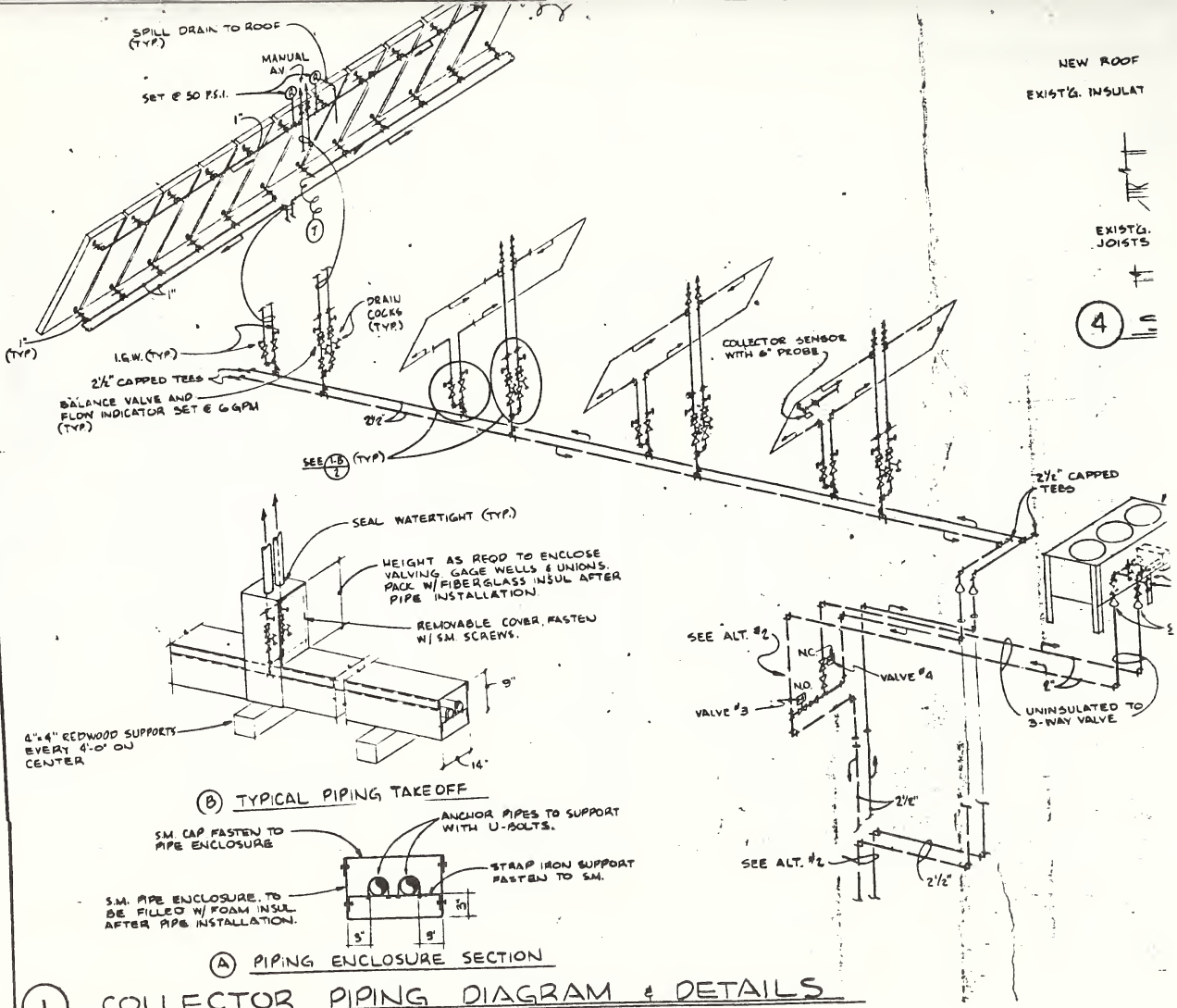
MECHANICAL ADD. PL

SOLAR S

CONRAD,

MONTANA
DRAPES ENGINEERING
A.G. DRAPES 1538E
7779
W.C. KILBY 1001E
PROFESSIONAL ENGINEERS

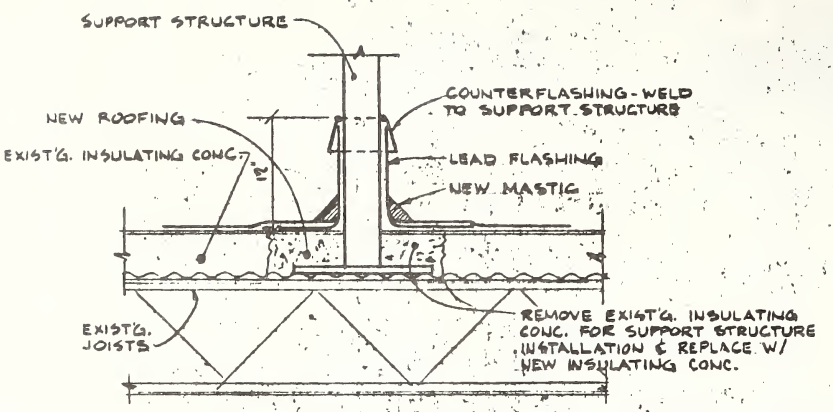
Drawn By
GO 'CS



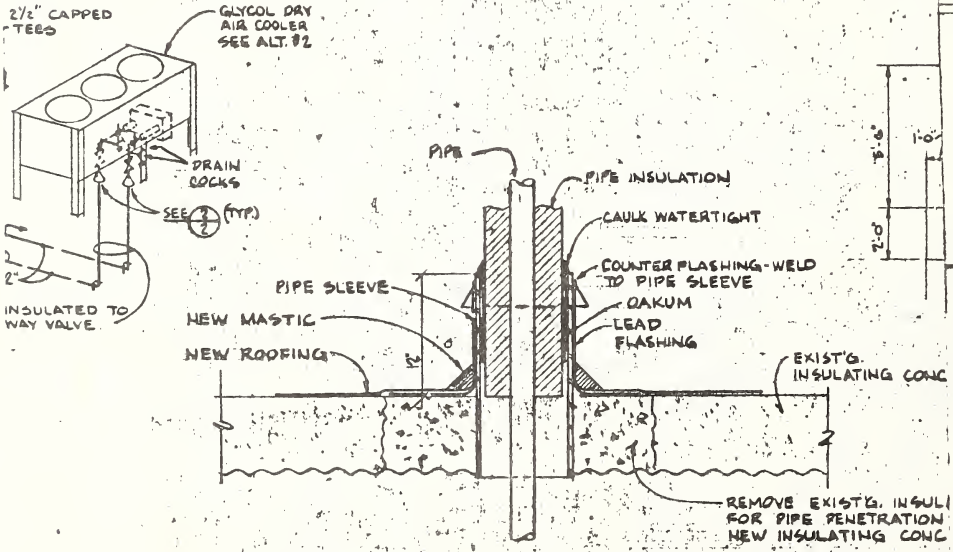
(B) TYPICAL PIPING TAKEOFF

(A) PIPING ENCLOSURE SECTION

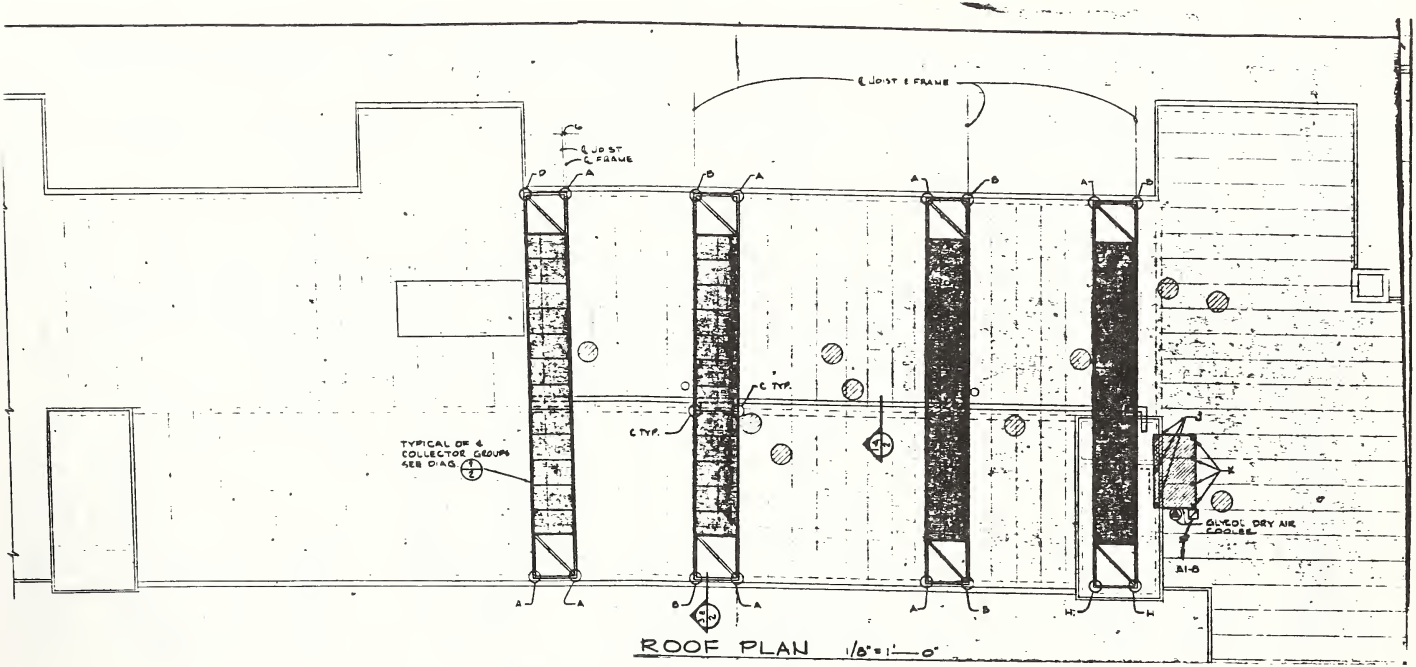
(1) COLLECTOR PIPING DIAGRAM & DETAILS



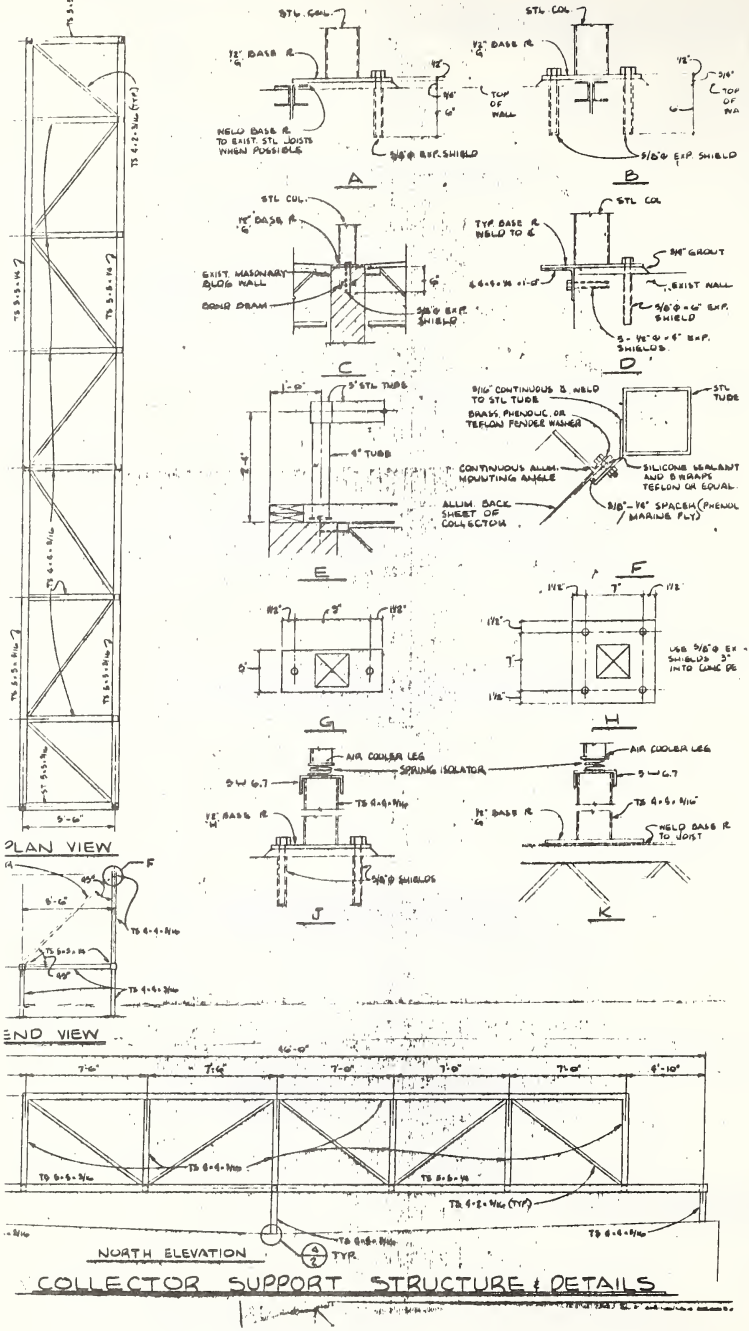
(4) SUPPORT STRUCTURE ROOF PENETRATION DETAIL NO SCALE



(2) PIPING ROOF PENETRATION



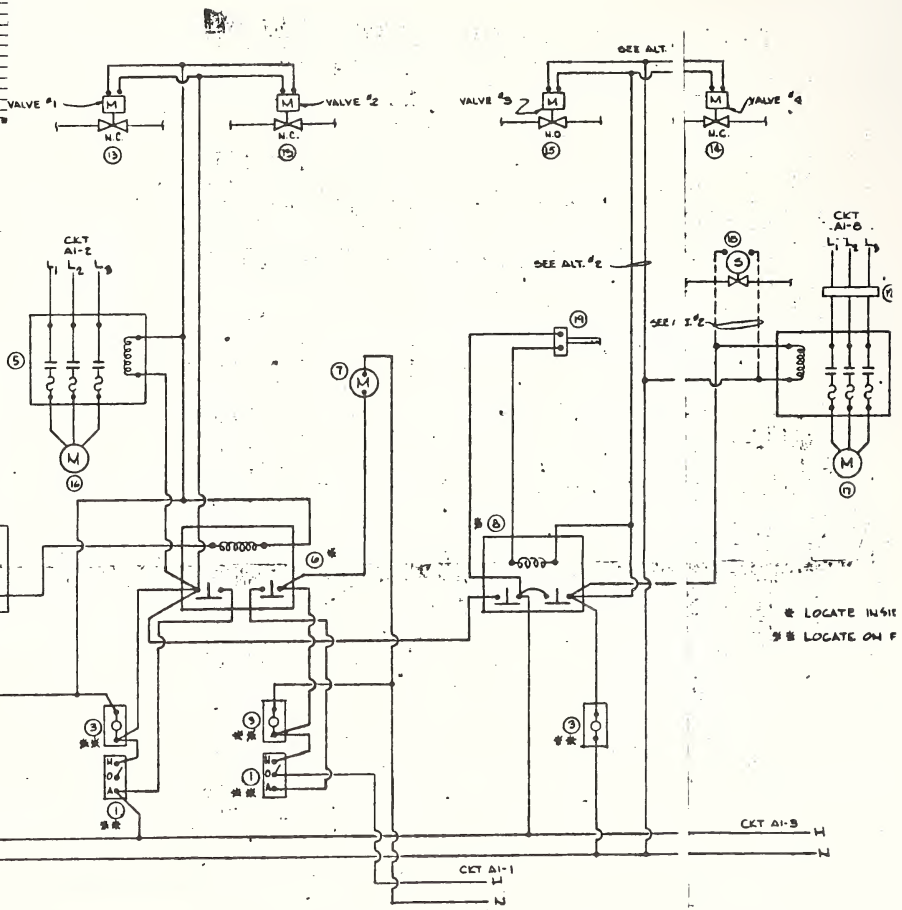
ROOF PLAN 1/8"=1'-0"



COLLECTOR SUPPORT STRUCTURE & DETAILS

PANEL A1 CHAR. 120/208V. 3 Ø 4 W MS 100A MOUNTING FLUSH
PANEL FEED TOP FEEDERS CU. 4 #3 THW - 3/4"C.
MISC.

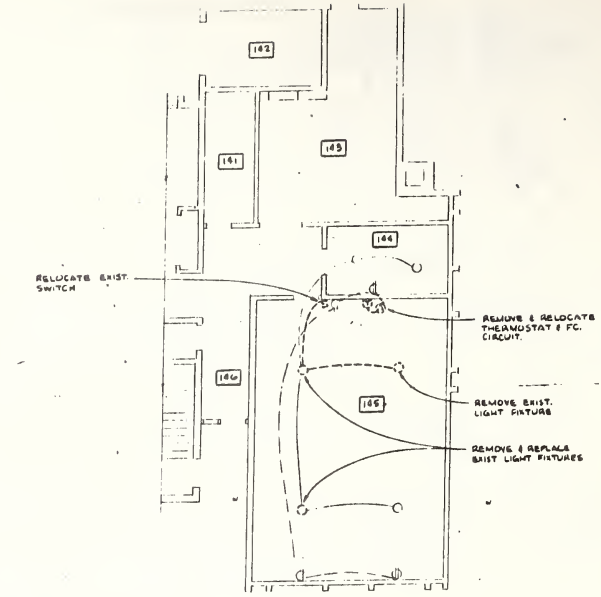
CKT	FRAME	WIRE	LOAD DESCRIPTION	CKT	FRAME	WIRE	LOAD DESCRIPTION
1	20A-1P	#12	PUMP #1	2	20A-3P	#12	PUMP #1 "
3		#12	SOLAR CONTROL PANEL	4		"	"
5		#12	E.O.	6			
7		#12	LIGHTS	8	30A-3P	#12	GLYCOL COOLER
9			SPARE	10		"	"
11			SPARE	12			
13			PROVISION	14	-3P		PROVISION
15			PROVISION	16			
17	20A-1P		PROVISION	18			
19				20			



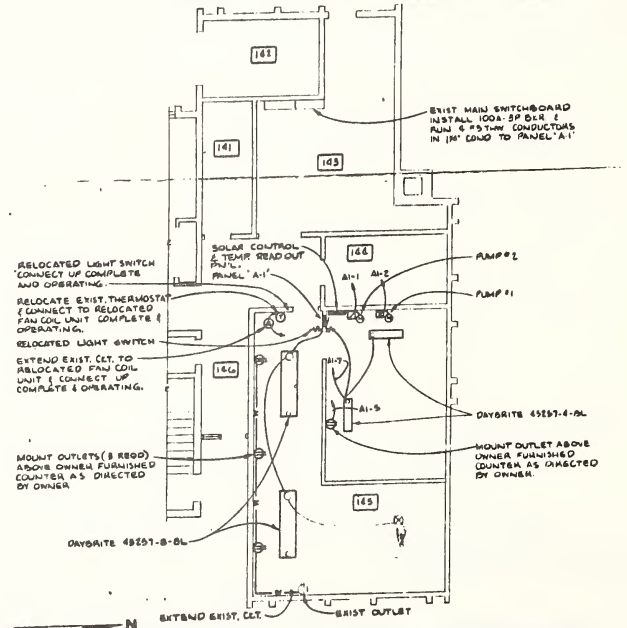
NOTES:

1. ON-OFF-AUTOMATIC SWITCH
2. ON-OFF SWITCH
3. PILOT LIGHT
4. DIFFERENTIAL THERMOSTAT AND COLLECTOR PUMP (PUMP #1) RELAY (RHO SIGMA #R5500)
5. COLLECTOR PUMP (PUMP #1) STARTER (SQUARE-D CLASS 8536, SIZE 0, 120-VOLT COIL)
6. COLLECTOR PUMP (PUMP #1) AND STORAGE PUMP (PUMP #2) RELAY (HONEYWELL #R4B2C1071)
7. STORAGE PUMP (PUMP #2)
8. STORAGE TANK HIGH LIMIT RELAY (HONEYWELL #R4B2C1071)
9. STORAGE TANK TEMPERATURE SENSOR (RHO SIGMA #SPT-XX, 24" PROBE)
10. COLLECTOR TEMPERATURE SENSOR (RHO SIGMA #SPT-XX, 6" PROBE)
11. GLYCOL COOLER CONTACTOR (FURNISHED W/UNIT)
12. GLYCOL COOLER DISCONNECT (30-AMP 3PST, WEATHERPROOF, NON-FUSED.
13. COLLECTOR SYSTEM SHUTOFF VALVES (ASCO #8210E49)
14. GLYCOL COOLER DIVERTING VALVE (ASCO #8210E49)
15. GLYCOL COOLER DIVERTING VALVE (ASCO #8210B69)
16. PUMP #1
17. GLYCOL COOLER
18. SOLENOID DRAIN VALVE (SEE ALT. #2 - ASCO #8210D22)
19. HIGH LIMIT SENSOR (HONEYWELL #L4408D1011)

CONTROL WIRING DIAGRAM



ELECT. DEMO PLAN 1/8" = 1'-0"



ELECT. ROOM ADD. PLAN - STORE RM #145 1/8"

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